Prof. Carey Foster, Prof. Hughes, Prof. Fleeming-Jenkin, Mr. Graves, and Mr. Preece. The full text of the resolutions is as follows:—

"I. *Electric Units*, strictly so called. First Resolution: The legal ohm is the resistance of a column of mercury of a square millimetre cross-section and 106 centimetres in length at the temperature of melting ice. Second Resolution: The Conference expresses the wish that the French Government should transmit this resolution to the different States, and recommend an international adoption of it. Third Resolution: The Conference recommends the construction of primary standards in mercury conformable to the resolution previously adopted, and the concurrent employment of scales of secondary resistances in solid alloys which shall be frequently compared amongst one another and with the primary standard. Fourth Resolution: The ampere is the current the absolute value of which is ten to the power minus one in electro-magnetic units. Fifth Resolution: The volt is the electromotive force which maintains a current of one ampere in a conductor the resistance of which is one legal ohm.

"II. *Earth-Currents and Lightning-Rods*. First Resolution: It is to be desired that the results of observations collected by the various administrations be sent each year to the International Bureau of Telegraph Administration at Berne, which will make a digest of them and communicate it to the various Governments. Second Resolution: The Conference expresses the wish that observations of earth-currents be pursued in all countries.

"III. *Standard of Light*. Resolution: The unit of each kind of simple light is the quantity of light of the same kind emitted in a normal direction by a square centimetre of surface of molten platinum at the temperature of solidification. The practical unit of white light is the quantity of light emitted normally by the same source."

DR. JOULE'S SCIENTIFIC PAPERS

The Scientific Papers of James Prescott Joule, D.C.L., LL.D., F.R.S., &c. (London: Published by the Physical Society, 1884.)

OUR benefactors are oftentimes unrecognised. The writer of the present notice of our latest acquisition in scientific literature, takes credit to himself for having been the first to propose to Sir William Thomson the reprinting of his original papers. Seized with a great desire to possess those invaluable electrostatic papers, which, in 1867, could only be read in the original by those who were fortunate enough to have access to the *Cambridge and Dublin Mathematical Journal*, he urged that there must be many others by whom a reprint would be gladly welcomed. Thus was originated the reprint of the "Electrostatics and Magnetism."

The initiative being taken, we have now a second series from Sir William Thomson—part published, part in progress—intended to include all his mathematical and physical papers. Prof. Stokes also, under the influence of pressure and good example, has produced the first half of a reprint of his classical papers. Abroad we have collections of the papers of Prof. von Helmholtz and Prof. Kirchoff. Last at the present moment, but far from the least in importance or in general interest, we have the first volume of republished papers by Mr. Joule.

But what a debt of gratitude we owe to the Physical Society for its publishing enterprise—first for the publication of Prof. Everett's "Illustrations of the C.G.S. System," a book which has been helpful to every student of physical science; then for its graceful tribute to the memory of Wheatstone; and now for this fresh and most happy undertaking.

Before looking at the papers themselves, let us unburden ourselves of one or two remarks. The form of the book is admirable. The printing and the diagrams are all that can be desired. The accuracy of the author of the papers, who has personally undertaken the editing, appears in that there is scarcely a misprint to be found in the 650 pages. One serious want, and one only, we have felt, and it is this. Throughout the book there are many back references to previous papers. These references are given in footnotes exactly as they were given in the original papers, thus, *Phil. Mag.*, ser. 3, vol. xiii. p. 268. But what the reader of the book wants, nay absolutely requires, is the reference to the page of the reprint itself where the passage alluded to is to be found. May we be allowed to suggest this as an improvement for the second volume now promised?

To come to the papers themselves, almost one hundred in number. There is a considerable number of unconnected papers on a great variety of subjects, several on meteorological phenomena, six or eight on new instruments or modifications of instruments, a mercurial pump, an improved barometer, a new dip circle, a current meter, &c., in addition to his tangent galvanometer, and one or two others to which we will immediately refer more particularly; then we have a paper on utilisation of sewage; a note on the prevalence of hydrophobia; improvements in the common kite, &c.: all of considerable value. For the most part, however, the papers are on two or three classes of subjects very closely connected, and these are of superlative interest, containing, as they do, the germs, or rather affording the foundation, of the modern theory of energy.

Mr. Joule's papers are remarkable in form as well as in substance. Of mathematics there is scarcely a line: but what clearness, and depth, and penetration into the hidden things of Nature! Thus their interest is general to an unusual degree. To those who shun the labour of arriving at results by "chasing the ρ" through mazes of equations they are the perfection of clear exposition of fundamental principles. The mathematician, on the other hand, finds in them a model of concise expression, and results of experimental investigation stated in a form ready and convenient for being represented in mathematical symbols.

It is impossible within the limits to which these lines are necessarily confined to notice exhaustively the investigations themselves, or even the results arrived at. We must content ourselves with a brief reference to some of the most important.

The first subject which seems to have attracted the attention of Mr. Joule was that of magnetism and the electro-magnetic engine. His earliest papers are taken up with the description of novel forms of the electro-magnetic engine, and of experiments in this connection. In a very early paper he investigates the laws relating to

what is now commonly spoken of as the *back electromotive* force of a motor. In connection with these researches Mr. Joule obtained valuable results with regard to the construction and the efficiency of various forms of magnets, both permanent magnets and electro-magnets, and he was led also to improvements in the galvanometer which, in the form of the tangent galvanometer, he afterwards perfected.

These experiments led naturally to investigations on the connection between heat, electricity, and mechanical energy, and to a comparison between electricity obtained from chemical action and that obtained from magneto-electric machines, and also to an examination into the heat given out during electrolysis.

A paper of March 1841, on the heat evolved by metallic conductors of electricity and in the cells of a battery during electrolysis, is of special interest. It is here that the law is first announced that the heat developed by a current of electricity, whether through a metallic conductor or in an electrolytic cell, is proportional to the resistance and to the square of the current. It is proved that the whole heat generated by a voltaic battery is proportional to the chemical action which goes on in each cell of the battery multiplied by the whole "intensity" or electromotive force; and the localities at which the several portions of the heat developed in a compound circuit, are clearly distinguished, and the quantities of heat developed in each part are determined.

In this paper improvements in the galvanometer are referred to. A "degree of electricity," or unit-current, is defined as "the quantity of current electricity which is able to electrolyse a chemical equivalent expressed in grains in one hour of time." Hence the results in this paper, and in many others which follow and in which the same *degree* is used, are now easily reducible to absolute measure. His degree was somewhat less than two amperes, or one-fifth of the absolute C.G.S. unit. In this paper also he defines his *first unit of resistance*—a wire of copper ten feet long and 0·024 of an inch in diameter (about No. 23 B.W.G.); and it is curious and somewhat amusing to find that the copper wire which Joule used for this unit must have been preternaturally *bad!* If the wire had been of "conductivity" copper, such as is now universally insisted on, the resistance would have been 0·167 ohm. An easy calculation from Joule's results shows that the resistance must have been at least one-half more! It was not until the manufacture of the 1858 Atlantic cable was in progress that it was found that variations, not previously dreamed of as possible, were commonly to be met with in the conductivity of copper wire.

A most interesting paper on the electric origin of the heat of combustion, also in 1841, naturally follows that just referred to. It is in this paper that Joule determines the *electromotive force necessary to decompose water.* He finds it to be 2·8 of Smee's elements, and then proceeds to similar determinations for various chemical compounds used as electrolytes.

Space fails altogether for mentioning the multitude of interesting results, then perfectly unknown, which Joule brings out in these early papers. Many of them have played important parts in guiding and in assisting other investigators. We find tests recorded as to permanency of resistance coils. We have investigations of the resistance of electrodes of various materials in various electrolytic cells. Joule's early (1841 to 1844) determinations enabled Sir William Thomson in 1851 to calculate in absolute measure the electromotive force of a Daniell's cell. He found it to be 2,507,100 British absolute units or 1·0739 volt! It is doubtful whether we are assured of a better result at the present day.

We must notice next the series of papers containing Joule's researches on the dynamical equivalent of heat, unquestionably the most important of all his investigations. The complete and successful prosecution of this investigation belongs to Joule, and to Joule alone. The methods are his; the carrying out of the experiments is his. The result will ever be known under the honoured name of "Joule's equivalent."

It is interesting to notice the first germ of the idea, and to be enabled to follow, from its commencement to its conclusion, the series of experiments which gradually brought out the result with which we are now so well satisfied.

In a paper dated January 24, 1843, we find the first mention of the idea as follows:—

"The magnetic electrical machine enables us to convert mechanical powers into heat by means of the electric currents which are induced by it. And I have little doubt that, by interposing an electro-magnetic engine in the circuit of a battery, a diminution of the heat evolved per equivalent of chemical change would be the consequence, and this in proportion to the mechanical power obtained."

A note dated February 18, 1843, is as follows:—

"I am preparing for experiments to test the accuracy of this proposition."

The results of the experiments alluded to in the note just quoted were given to the British Association at its meeting at Cork, in a paper read on August 21, 1843, "On the Calorific Effects of Magnetic Electricity, and on the Mechanical Value of Heat." The experiments were made by rotating "an electro-magnet immersed in a vessel containing water between the poles of a powerful magnet, to measure the electricity thence arising by an accurate galvanometer, and to ascertain the caloric effect of the coil of the electro-magnet by the change of temperature in the water surrounding it."

Permanent steel magnets were first employed for producing the magnetic field, and afterwards a huge stationary electro-magnet was used for this purpose. The writer of the present notice well remembers the interest with which this great rough magnet and its accompaniments were viewed, by some of the foreigners who visited the Loan Collection of Scientific Apparatus at South Kensington in 1877.

Joule's conclusion, given to the British Association at this time was that the mechanical equivalent of a water pound-degree Fahrenheit of heat was 838 foot-pounds of work. In a postscript to this paper, of date August 1843, he says:—

"I have lately proved experimentally that *heat is evolved by the passage of water through narrow tubes.* My apparatus consisted of a piston perforated by a number of small holes working in a cylindrical glass jar containing about 7 lbs. of water. I thus obtained one degree of heat per pound of water from a mechanical force capable of raising about 770 lbs. to the heigh of

one foot, a result which will be allowed to be very strongly confirmatory of our previous deductions."

In 1844 we have a paper communicated to the Royal Society on "Changes of Temperature produced by the Rarefaction and Condensation of Air." This paper was not accepted by the Royal Society for its *Transactions*, and the *Philosophical Magazine* had the honour of publishing it! In 1845, in a paper read before the British Association, he describes experiments made by stirring water with a "sort of paddle-wheel" in a "can of peculiar construction;" and in 1846 this was followed by an important paper on "Heat disengaged in Chemical Combinations."

It was, however, in 1849 that his celebrated paper "On the Mechanical Equivalent of Heat" was communicated by Faraday to the Royal Society. This was the first of Joule's papers which was communicated to and *not* rejected by the Royal Society, and *it* was rewarded by a Royal Medal! In this paper he describes experiments (1) on friction of water; (2) (3) friction of mercury, two series of experiments; (4) (5) friction of cast-iron, two series. From all these he concludes:—

"(1) *That the quantity of heat produced by the friction of bodies, whether solid or liquid, is always proportional to the quantity of force expended; and*

"(2) *That the quantity of heat capable of increasing the temperature of a pound of water* [*weighed* in vacuo *and taken at between* 55° *and* 60°] *by* 1° *F. requires for its evolution the expenditure of a mechanical force represented by the fall of* 772 *lbs. through the space of one foot.*"

In 1867 a report was communicated to the British Association through the Committee on Standards of Electrical Resistance, containing the results of fresh experiments on the dynamical equivalent of heat. Finally, at the desire of this Committee, and aided by funds placed at his disposal by the British Association, Mr. Joule undertook a complete redetermination. This was commenced in 1870, and his report was given in 1878. Here is his conclusion, stated in the last two sentences of the present volume:—

"The equivalent at the sea-level and the latitude of Greenwich will therefore be 773·492 foot-pounds, defining the unit of heat to be that which a pound of water, weighed by brass weights when the barometer stands at 30 inches receives in passing from 60° to 61° F. With water weighed *in vacuo* the equivalent is finally reduced to 772·55."

It is impossible for us to do more here than mention some of the other papers contained in this volume. Perhaps among those which are of highest importance we should refer first to a short paper "On the Theoretical Velocity of Sound," in which outstanding difficulties are cleared up, and deductions as to the true relation between the specific heat of air, volume constant, and the specific heat, pressure constant, are brought forward. We have also important experiments on "Some Amalgams," in which their mode of production and characteristics are dealt with. A paper "On Surface Condensation of Steam" was largely conducive to the great improvement which the substitution of this method, for condensation by injection, has realised in the condensing engine of the present day.

In connection with his very earliest work Joule gave special attention to the construction of thermometers. He was the first to produce accurate thermometers in England, as Regnault did, just about the same time, in France. Joule's thermometers were made for him by Mr. Dancer of Manchester. In 1867 we have a paper "On the Alteration of the Freezing-Point," giving the results of the observations of five-and-twenty years on this curious phenomenon. In the present volume the paper is supplemented by observations carried down to December 1882.

We mention, lastly, his papers describing experiments to test the brittleness supposed to be imparted to iron castings by frost—experiments which, so far as they go, negative altogether the popular idea on the subject; and with this mention we must take our leave of the volume, expressing once more our deep appreciation of its value, and earnestly hoping for the speedy appearance of its promised companion.

LETTERS TO THE EDITOR

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, or to correspond with the writers of, rejected manuscripts. No notice is taken of anonymous communications.*

[*The Editor urgently requests correspondents to keep their letters as short as possible. The pressure on his space is so great that it is impossible otherwise to insure the appearance even of communications containing interesting and novel facts.*]

Long or Short Fractions for Great Natural and National Standards—Earth's Axis of Rotation

In the two last numbers of the *American School of Mines Quarterly Journal* the learned President Barnard of Columbia College, New York, has involuntarily opened a question of far wider interest than the particular one with which he set out. For on his page 120 there stands the following remarkable statement:—

"The length of the polar axis of the earth is a quantity which may with strict truth be pronounced to be, up to this time, absolutely unknown."

Now if that really be so, the peoples of every civilised country on the face of the earth, who have been taxed during the last hundred years to the extent of millions and millions for the support of magnificent arc-of-the-meridian measuring establishments, have some right in common sense to rise with revolutionary wrath, and demand how those enormous sums of their money, given to determine the size and shape of the earth, have been expended. And when shall we know the far greater distance of the sun!

But the statement can only be true on some private interpretation which is needless to inquire into; for when we take the various lengths of the earth's axis of rotation as determined in modern times, and collected by President Barnard himself from very diverse sources indeed, we find them all to be coincident to four places of figures at least. And considering that for some other most important natural standards the world is apparently content with a certainty of two places of figures only, the officers of the several trigonometrical establishments of all the countries of Christendom deserve high praise, rather than blame, for the results they have succeeded in bringing out.

The mean of their last five measurements, as given by President Barnard for the polar axis of the earth, is

500,492,732·8 British inches,

the ten-millionth part of which is evidently

50·04927328 British inches;

though *he* has chosen to bring it out as a very different quantity indeed, viz. 49·273 British inches.

But the rather important point now to be discussed is, whether in practical use as a standard of measure, either on paper or for mechanical work, we should attempt to realise that long fraction; or be content with the

50·05 British inches,

at which, as quoted by the President, I had years ago ventured to assume the said ten-millionth of the earth's axis of rotation.

In place of merely, and perhaps vainly, *theorising* on the sub-